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Lowering barriers to engage in innovation: evidence from the Spanish innovation Survey

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1 Introduction

Innovation studies have extensively examined the drivers and sources of innovation, paying particular attention to the technological and organizational capabilities that firms need to develop to become successful innovators (e.g. Schumpeter, 1950; Dosi, Nelson and Winter, 2002; von Hippel, 1994). This literature, however, has been comparatively less systematic in examining the factors that block innovation or cause innovation failures.[1] Redressing this unbalance is crucial for at least two reasons. On the one hand, from an innovation policy perspective, it is important to identify the entry barriers faced by potentially innovative firms, in order to foster innovation-based competition dynamics and attenuate systemic failures to innovation (Woolthuis, 2005; Chaminade et al., 2009). On the other hand, from an innovation management perspective, it is important to identify the obstacles most commonly faced by firms along their innovative activities, in order to enhance the economic pay-offs from innovation-related efforts (Dougherty, 1992; Ferriani et al., 2008).

This papers aims at improving our understanding of the factors attenuating obstacles to innovation by distinguishing between firms that face *deterring* barriers to innovation and firms that confront *revealed* barriers to innovation (D'Este et al., 2008). As discussed throughout the paper, making this distinction between *revealed* and *deterring* is crucial to help disentangling two essentially different mechanisms when referring to 'obstacles to innovation'.

This research draws on four successive waves of the Spanish Innovation Survey (i.e. years 2004, 2005, 2006 and 2007) to construct a longitudinal dataset on firms' innovation profiles. In order to avoid a sample selection bias problem, we consider only firms that are willing to participate in the innovation contest (i.e. we filter out firms that are not interested in undertaking innovation activities (see Savignac, 2008, for a similar method). We distinguish two groups of firms: one confronting deterring barriers and another one confronting revealed barriers (using a propensity score matching procedure). We finally examine whether firm characteristics contribute to attenuate the barriers experienced by firms, for each of the two groups separately.

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[1] Though there has been an increasing attention to this topic in recent years: e.g. Baldwin and Lin, 2002; Galia and Legros, 2004; Tourigny and Le, 2004; Tiwari et al., 2007; Savignac, 2008; Iammarino et al., 2009; among others.

The paper is structured as follows. Section 2 provides the background discussion for the study and put forward a number of hypotheses. Section 3 presents the data sources and the method. Section 4 presents the results and Section 5 concludes.

2 Barriers to innovation: background discussion

Innovation has long been recognised as a vital contributor to firm economic performance and survival. Both the scientific literature and the policy agenda have consistently highlighted the importance of investment in innovative activities to reach further economic competitiveness and secure economic growth and higher living standards. Firms have extensively internalised this argument, with corporate strategies increasingly geared around innovation.

However, despite the ample support to the discourse in favour of innovation, many firms remain persistently detached from any deliberate effort towards innovation activities, and even further removed from any significant innovation achievement. For instance, drawing upon the Spanish Innovation Survey 2007, for the whole sample of *potentially innovative*[2] firms, 30%[3] did not conduct any innovation related activity in 2007. This phenomenon was not exclusive of firms in low-tech industries; among firms in high and medium technology manufacturing industries, about 16% of the potentially innovative firms did not invest any money in innovation-related activities. For knowledge intensive business services (KIBS), the corresponding percentage was 20%.

This is striking since our definition of innovation-related activities is quite broad, encompassing expenditures in tasks that range from "activities for the market preparation and introduction of new (or significantly improved) goods and services", "acquisition of machinery or equipment to produce new (or significantly improved) goods or services" and "internal or external training of personnel involved in development or introduction of innovations". The set of activities includes also expenditures in formal R&D, but it clearly expands well-beyond this category.

If a substantial portion of the potentially innovative firms do not invest in innovation-related activities, it is plausible to claim that the innovation system is suffering from systemic failures to innovation. Following Chaminade and Edquist (2006) and Chaminade et al. (2008), we define systemic failures to innovation as factors weakening the capabilities of firms to engage in interactive learning and innovation, and therefore, hampering innovation at a system level. Systemic failures to innovation include: a) the lack of private institutional support for innovation, as for instance the restricted availability of finance for activities that entail high levels of risk and uncertainty; b) the lack of information on technological and market opportunities for innovation, as a consequence, for instance, of a weak connectivity between organizations in the innovation system; c) the lack of an adequate scientific and research infrastructure, as for instance, the weakness in the supply of an adequate skill-base from secondary and tertiary education; and d) the characteristics associated with the market structure and the potential entry barriers from incumbents; among

[2] In here, we follow Savignac (2008) and D'Este et al. (2008) by filtering out those firms that are not in the innovation contest – those that are not oriented or willing to innovate. We explain this in more detail in Section 3.2 below.

[3] More specifically: 3113 firms out of 10316.

other factors.

One first indication of the extent to which barriers to innovation are prevalent among firms in a particular system, is provided by the proportion of firms that assess that certain factors have been 'highly important' in hampering their innovation activities or shaping their decision of not engaging in innovative activities. As Table 1 (column 1) shows (based on the Spanish Innovation Survey 2007), factors associated with availability of finance are deemed as the most important barriers for firms (about 30% of firms reporting that these barriers have been very important), followed by market related barriers (about 20%) and knowledge related barriers (about 10%).

However, the figures in column 1 mask an important feature of the impact of barriers on innovation. Among potentially innovative firms, those that have not engaged in innovation activities at all are more likely to exhibit higher barriers to innovation, compared to those firms that engage in innovative activities. As columns 2 and 3 show, these differences in the assessment of barriers apply to almost all barrier-items with the exception of two finance-related barrier items (i.e. 'lack of available internal finance', for which there are no significant differences between the two groups of firms, and 'lack of available finance from other organisations', for which differences run in the opposite direction).

Table 1: Proportion of firms assessing barriers as "highly important"

Barrier items	**Total sample (n = 10316)**	**Firms not investing in innovation activities (n=3113)**	**Firms investing in innovation activities (n=7203)**
Cost barriers:			
Direct innovation costs too high *	34.3	35.4	33.8
Lack of available internal finance	30.7	30.2	31.0
Lack of available finance from other organisations ***	28.6	25.4	29.9
Market barriers:			
Market dominated by established firms **	20.3	21.7	19.7
Uncertain demand for innovative goods or services ***	21.4	23.3	20.5
Knowledge barriers:			
Lack of qualified personnel ***	13.4	15.6	12.5
Lack of information on technology ***	8.2	10.0	7.5
Lack of information on markets *	8.5	9.2	8.1
Difficulties to find appropriate innovation partners ***	12.3	13.9	11.6

Notes: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$, Chi-square tests for the null hypothesis that assessment of barriers (as important) is independent of whether the firm has invested in innovation-related activities or not.

Table 1 provides some preliminary evidence showing that firms that have not engaged in innovation-related activities are particularly sensitive to barriers. Or, in other words, the figures in Table 1 indicate that we should differentiate two different mechanisms of barriers on innovation activities: those barriers that deter firms from engaging in innovative activities, and those barriers that are faced by firms while engaging in innovative activities. Since the group of firms facing deterring barriers is willing to innovate but is prevented from entering in the innovation contest, it is in this case that the systemic failures to innovation can be felt more acutely, and are more likely to impose a higher social cost in terms of weaker competition intensity and lower innovation achievements.

2.1 Deterring versus revealed barriers to innovation

In this section we argue that it is important to distinguish two mechanisms through which barriers to innovation operate. On the one hand, barriers operate by deterring firms from engaging in innovation activities. This happens when firms that would be willing to undertake innovative projects, choose not to become active in innovation-related activities. This decision is likely to be the result of the firm lacking access to finance for high-risk projects, lacking adequate channels to obtain information about markets or technologies, facing obstacles for the recruitment of high-skilled employees, or having difficulties in meeting adequate partners for innovation activities, among other reasons. In short, deterring barriers refer to obstacles that prevent or block firms from undertaking innovative activities. Baldwin and Lin (2002), for instance, examine this type of barriers when investigating the importance of impediments faced by firms with regards to the adoption of advanced technologies.

On the other hand, barriers operate by obstructing the activities of firms that do engage in innovation projects. These barriers may simply delay or slow down innovation projects, or they may represent a major determinant of the decision to abandon an innovation project. Nevertheless, in these cases barriers do not prevent firms from initiating an innovation-activity, but may impose a substantial obstacle to its completion. For this reason we categorize these barriers as “revealed” barriers, since these barriers are only observed once firms engage in innovation activities. In other words, revealed barriers refer to obstacles to innovation that are realised by firms alongside their innovation-related activities. This is the type of barriers addressed in the literature when looking at financing and the costs involved in bringing an innovation to market (e.g. Baldwin and Hanel, 2003).

It is also important to make a distinction between these two types of barriers from the point of view of innovation policy. If policy makers aim at addressing systemic failures in the innovation system, it is crucial to identify the extent of the problem (that is, the proportion of potential innovators that are detached from innovation activities) as well as to identify the main features of the actors deterred from engaging in innovation activities, in order to help design appropriate policies that confront systemic failures (Chaminade and Edquist, 2006). In other words, we need to gain a better understanding of the systemic factors that prevent firms from being innovation-active. Preliminary evidence in this sense has been provided by Mohnen and Roller (2005) who show that, when it comes to turn non-innovators into innovators, a system approach is needed that takes into account the complementarities between obstacles.

2.2 Attenuating barriers to innovation

The main objective of this study is to improve the understanding of the factors attenuating obstacles to innovation. We approach this objective by distinguishing between firms that face *deterring* barriers to innovation and firms that confront *revealed* barriers to innovation, since the dynamics at work might differ between these two groups of firms with regards to the lowering of barriers. Drawing upon the literature on innovation studies, we would expect the following factors to attenuate deterring and/or revealed barriers to innovation.

a) Firm size

We expect that the size of the firm should have an attenuating effect on both deterring and revealed barriers to innovation. This is because larger firms are more likely to draw on an internal pool of financial and knowledge-related resources, as well as benefiting from scale advantages to spread the fixed costs of innovation over a larger volume of sales. This makes larger firms less vulnerable to entry and revealed barriers to innovation (e.g. Schoonhoven et al., 1990; Cohen and Klepper, 1996; Katila and Shane, 2005). Additionally, we would also expect that the attenuating effect of size is likely to be stronger for deterring than for revealed barriers, since organizational complexity and routines can offset the advantages associated to size among firms already engaged in innovative activities (Tushman and Anderson, 1986; Christensen and Bower, 1996).

b) Being a start up

There are two conflicting arguments with regards to new firms: the creativity and entrepreneurial dynamism associated with start ups and the liability of newness. On the one hand, we would expect that recently established firms are more likely to participate in innovative activities than established firms, since new firms might be less constrained by the risks of cannibalising existing product portfolios or destabilizing core competencies (Tushman and Anderson, 1986; Henderson, 1993). However, on the other hand, start ups are comparatively more likely to confront barriers to innovation due to a lack of prior expertise, scarcity of financial resources or lack of complementary assets (Schoonhoven et al., 1990; Tripsas, 1997).

c) Human capital

The availability of highly skilled employees, and particularly of employees with a higher education degree, is expected to equip firms with an adaptable, responsive and pro-active workforce, softening the challenges imposed by changes in market conditions and the emergence of disruptive technologies (e.g. Gibbons and Johnston, 1974; Cohen and Levinthal, 1990; Baldwin and Lin, 2002). Building upon this, we would expect that firms with a higher proportion of highly skilled employees would be better positioned to overcome both deterring and revealed obstacles to innovation.

In assessing the impact of the above factors, it is important to control for some important individual and environmental features that might affect the capacity of firms to face barriers to innovation. On the one hand, the extent to which the firm has been systematically engaged in innovation-related activities in the past (or whether it has never been active in innovation activities before). We would expect that firms that have, at some previous point in time, been engaged in innovation-related activities, should be better positioned to face barriers to innovation (compared to firms that have not been involved in the past).

On the other hand, we control for the extent to which the firm has been recipient of public financial support to innovation. Most countries have implemented policies to boost innovation, either by subsidising highly risky innovative projects or offering fiscal incentives to firms that plan to expend a substantial proportion of resources in internal innovative activities. We would expect that firms that have been recipients of this type of support from public programmes, are going to be better positioned to face entry barriers to innovation. However, for those firms that engage in innovative activities already, being recipient of this type of governmental support may actually enhance the perception of revealed barriers, since such programmes may contribute to intensify the firms' engagement in more complex or ambitious innovative activities that bring associated a heavier requirement for financial support or knowledge-related capabilities.

3 Data and Method

3.1 Data sources

The data set used in this paper contains firm level data from the Spanish Technological Innovation Panel (PITEC). The data is collected by a joint effort of the Spanish National Statistics Institute (INE), the Spanish Foundation for Science and Technology (FECYT), and the Foundation for Technical Innovation (COTEC). PITEC is organized as a panel data set, with a relatively consistent data collection methodology over a number of time periods. The unit of analysis (i.e. each observation) is the single enterprise, whether part of a larger group or independent. The data comes from a CIS-type survey, based on the OECD's Oslo Manual, and therefore includes information related to innovation activities comparable with the microdata on innovation of many other European Countries. This database is placed at the disposal of researchers on the FECYT website (http://sise.fecyt.es), and is available in a set of coordinated files, i.e., a file each year (2003, 2004, 2005, 2006 and 2007). In this paper we use specifically the data from the period 2004-2007[4]. PITEC has a wide sectoral coverage including both manufacturing and service sectors.

The sample corresponding to the last collection of data is composed by 12808 firms with an important representation of firms with innovative activities (around 70%). In order to have a longitudinal dataset with a consistent number of firms in all years, we have excluded those which have experienced any important contingency during the period 2004-2007 (that is, those for which we had missing values in some of the years of that period). Such contingencies are generally related to problems with the access to the firm or confidentiality issues and problems associated to mergers and acquisitions or changes in the industrial activity that made it impossible to trace the enterprise unit throughout the period. In addition we have excluded those cases where no information was found about economic activity and also the firms belonging to the primary sector (agriculture and mining). The result was a sample of 6606 firms with non-missing values and with data for four waves of the Spanish innovation survey.

[4] Although PITEC provides information from 2003, we do not use the data for this year because the sampling procedure had important limitations. For reasons of opportunity and viability, PITEC started with only two samples in 2003: a sample of firms with 200 or more employees and a sample of firms with intramural R&D expenditure. This limitation was corrected from 2004 by including a sample of firms with fewer than 200 employees, external R&D expenditure and no intramural R&D expenditure; and a representative sample of firms with fewer than 200 employees and no innovation expenditure.

The advantage of using this dataset is that it allows us to address econometric endogeneity issues by introducing lagged variables as explanatory variables. By doing so, we can examine, for instance, the relationship between the assessment of barriers and the extent to which firms have engaged in past innovation activities or have received public support for innovation in a previous period. Specifically, in the analyses presented in this paper, the variables associated to barriers to innovation are taken from the 2007 survey, while the explanatory variables are taken from the 2006 or previous surveys[5].

3.2 Filtering process of 'potential innovators'

In line with previous work (see D'Este et al., 2008; Monhen et al., 2008; Savignac, 2008), we filter out from our sample those firms that do not aim at innovating. This is done in order to correct for a sample selection bias problem, which emerges from asking all surveyed firms (irrespective of their willingness to engage in innovative activities) about obstacles to innovation.

As reported in many studies (Baldwin and Lin, 2002; Mohnen and Roller, 2005; Savignac, 2008), it is found a positive correlation between the experience of barriers to innovation and the probability that a firm innovates or engages in innovative activities. As Savignac (2008) points out, this counterintuitive positive relationship is strongly dependent on the inclusion in the sample of firms that are not willing to innovate: those that did not engage in innovative activities at all and that did not encounter any obstacle to innovation. Indeed, firms not aiming at innovating do not carry out innovation activities at all and, for this reason, are more likely to report obstacles to innovation as not important. The positive relationship between the extent of innovation activity and the assessment of innovation obstacles is thus only a spurious relationship.

In order to avoid biases resulting from the inclusion of firms that are not 'potentially innovative' firms (i.e. not willing to engage in innovative activities of any sort), it is necessary to distinguish non-innovating firms in two main categories: (i) firms not willing to innovate, i.e. those that do not carry out any innovation activity and, at the same time, do not experience any barriers to innovation and (ii) "potential innovators", i.e. firms either reporting themselves as innovation active or experiencing some sort of barriers to innovation. By dropping from the analysis the firms belonging to the first group, it is possible to correctly estimate the sign and the intensity of the relationship between the propensity to innovate and the firm assessment of barriers to innovation. Indeed, by doing that, previous work finds out that the positive correlation between the two characteristics of interest actually becomes a negative one (Mancusi & Vezzulli, 2009 and Savignac, 2008).

In the setting of this study, we keep only those firms that are oriented to innovation in the period 2004-2007 (i.e. we exclude from our sample 1276 firms, about 19,3% of

[5] We have decided to restrict our analysis to these two waves of the innovation survey for two main reasons. First, the information about the proportion of highly skilled employees is available in the PITEC database from the 2006 survey only. Second, questionnaires corresponding to 2004 and 2005 have undergone some changes that could affect the temporal consistency of the data; while compared with 2006, the questionnaire corresponding to 2007 does not show changes. In spite of this fact, when it has been possible, we have used some variables taken form the 2004 and 2005 survey to carry out a number of robustness checks.

our longitudinal sample). In order to identify this group we used the information contained in the Spanish Innovation Survey. In particular, the survey includes two questions asking whether the firm has been engaged in innovation activities during the last three years and whether it has experienced any barriers to innovation during that period. If the firm responds negatively to these questions, we classified the firm as non-innovation oriented. The underlying rationale is that firms that did not carry out innovation activities and did not experience any barrier to innovation are unlikely to have any aspiration to innovate. Indeed, about 54% of these companies also indicated that innovation was not necessary in their respective markets because of the lack of demand for innovations. After this procedure we are left with a sample containing 5330 firms.

3.3 Measures

In order to obtain a measure of the assessment of innovation obstacles, we have drawn on the responses to a question on the Spanish innovation survey on factors hampering innovation that asked: "During the three-year period 2005-2007, how important were the following factors as constraints to your innovation activities or influencing a decision not to innovate?". The questionnaire distinguishes between nine types of factors, grouped into three sets of barriers: a) cost factors; b) knowledge factors; and c) market factors (see Table 1 for a description of the nine barrier items). We have chosen not to investigate the nine barrier items individually, but the three sets of barriers mentioned above. In order to do this, we have measured the extent to which firms assess barriers as important in three different ways. The first one is based on the construction of a dichotomous variable, indicating whether the firm assesses as important at least one barrier item (i.e. the variable takes the value 1 if the firm has assessed as highly important at least one barrier within each set, and takes the value 0 otherwise). The second one is a categorical ordered variable, representing the number of barrier items (within each barrier set) that are assessed as highly important.[6] And the third one based on the average assessment of all items in a particular barrier set – a variable that is bounded between 1 (if the firm assesses all barrier items as being of low importance) and 4 (if the firm assesses all barrier items as being highly important).[7]

As we mentioned in Section 2.2 one of the main objectives of this study is to identify the factors that may influence or attenuate the assessment of barriers as highly important. Following this, we have constructed the following three variables. First, a measure of firm size is included since previous research shows that larger firms are less vulnerable to entry and revealed barriers to innovation. This variable is measured as the natural logarithm of the total number of employees in 2006 (*Size*). Second, given that new firms could behave differently from established firms in terms of assessment of barriers, a variable that states whether or not the firm is a start-up is included (*Startup*). This variable takes the value 1 if the firm has been established after 1 January of 2002. Third, the proportion of the total employees with higher education degree is used as a proxy for the firm's human capital level. This variable is taken from the 2006 survey (*HumCap*).

[6] Thus, for instance, in the case of 'cost factors' the dependent variable ranges from 0 to 3, since firms may assess either none, one, two or all three cost-related items as highly important.

[7] In this case we distinguish between obstacles grouped in four sets of barriers: a) overall barriers (*ObsTot*); b) cost barriers (*ObsCost*); c) knowledge barriers (*ObsKnow*) and d) market barriers (*ObsMkt*).

We have also included, as control variables, three variables related to the extent to which the firm has been recipient of public financial support to innovation. These variables are taken from the 2006 survey and are dummy variables taking the value 1 if the firm indicates that it received public support for European (*PubSupEur*), National (*PubSupNat*) and regional/local governments (*PubSupLoc*) to support their innovative activities during the period 2004-2006. We also control for the firm's degree of engagement in innovative activities in the past. To this end, we include two variables: a) *InnInt* (innovation expenditures on total sales in 2006) and *Innexp* (this variable takes the value 1 if the firm has engaged in innovation activities during the period 2004-2006, and 0 otherwise). We also included a variable representing the market orientation of the firm (*IntMkt*), which is defined as a binary variable and takes the value 1 if the firm sells its goods or services in other countries.

Table 2: Descriptive statistics

	All observations (N=5330)			
	mean	Sd	min	max
ObsTot	2.57	0.67	1	4
ObsCost	2.8	0.94	1	4
ObsKnow	2.32	0.8	1	4
ObsMkt	2.79	0.95	1	4
NInn[8]	1.63	1.4	0	7
Size	4.19	1.5	0	10.02
Startup	0.07	0.25	0	1
PubSupLoc	0.3	0.46	0	1
PubSupNat	0.23	0.42	0	1
PubSupEur	0.06	0.23	0	1
HumCap	26.44	27.42	0	100
IntMkt	0.71	0.45	0	1
InnInt	22.43	258.82	0	13701.79
InnExp	0.79	0.41	0	1
IndMHT	0.08	0.27	0	1
IndMMT	0.24	0.43	0	1
IndMLT	0.35	0.48	0	1
IndSLT	0.11	0.32	0	1
IndSHT	0.21	0.41	0	1

Finally, we have included a set of five variables to control for the effect of sectoral characteristics. The sectoral dummies have been defined taking into account the distinction between low (*IndMLT*), medium-high (*IndMMT*) and high (*IndMHT*) technology sectors in manufacturing (as defined by Eurostat/OECD classification) and the distinction between High-tech-knowledge intensive service sector (*IndSHT*) and firms in other service sectors (*IndSLT*).[9] In Table 2 we provide descriptive statistics of the variables used in this study.

[8] Number of innovative activities

[9] According to the Spanish classification the group of High-tech knowledge-intensive service sector comprised the following economic activities: a) post and telecommunications, b) computer and related activities, and c) research and development.

3.4 *Examining differences in the assessment of barriers between matched groups of firms, using a propensity score matching procedure*

As discussed in Section 2, our aim is to investigate how different firm characteristics contribute to lowering deterring and revealed barriers to innovation. To do that, we need to distinguish which type of firms are experiencing each type of barrier. While from a conceptual point of view the distinction between the two types of barriers might be clear-cut (see Section 2), its operationalisation is much more difficult from an empirical viewpoint.

Two main issues are at work here which we need to cope with. First, no question is available in the Spanish Innovation Survey that allows us to clearly distinguish whether a firm is experiencing either deterring or revealed barriers. Second, firms can actually face at the same time both kinds of barriers, rather than only one of the two: there might be a "grey zone" where firms are neither *strongly* engaged in innovative activities nor completely deterred from engaging in innovation activities. For this reason, it is necessary to provide a separation as clear-cut as possible between firms facing deterring and revealed barriers. Thus, the first step is to individuate those firms that face clearly either revealed barriers or deterring barriers to innovation.

Our approach to identify differences between the two groups of firms relies on a quasi-experimental procedure by comparing outcomes for a treated[10] group of firms and a control group. We use the propensity score matching technique to identify a control group *without* markedly differences compared to target firms, based on a set of observed characteristics. The procedure consists of matching firms with a similar (or identical) estimated probability of carrying out a "certain" number of innovative activities, based on a set of observable characteristics.[11] Once this propensity score is calculated, observations from target and non-target firms are matched – each target firm is associated with a control firm endowed with a similar propensity score.[12]

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[10] In our case the treatment, or better the treatments, are defined as the specific numbers of innovative activities carried out by the firms belonging to a particular group.

[11] To obtain the propensity score, we estimate a logistic model where the dependent variable is a dummy variable taking value 1 if a 'selected' number of innovative activities is carried out and 0 otherwise. As explanatory variables, we make use of the most important factors stressed by the literature to explain firms' propensity to innovate: firm size, firm age, market power as well as environmental characteristics (e.g. technological opportunities, demand pull, etc.).

[12] Three main characteristics of propensity score matching are worth emphasizing: (i) no assumptions are made on the functional form of the relationship between explanatory variables and dependent variable; (ii) there must be a common support for treated and non-treated observations, that is there must be an overlap between the range of values taken by the relevant characteristics for the two groups otherwise it would impossible to provide a proper comparison and (iii) conditional on observable characteristics, the selection bias will disappear (selection on observables or conditional independence assumption).This last point implies that systematic differences related to unobservables may remain. Thus, a key maintained assumption is that, conditional on the vector of explanatory variables, the observed outcome under treatment and the potential outcome under no treatment are independent of assignment to treatment. Nevertheless, it might be the case that unobservables affecting the outcome affect assignment to the treatment group as well. In this case, the selection on observables assumption cannot be maintained anymore and propensity score matching is not able to consistently estimate the effect of treatment on the outcome variable. Unfortunately, the assumption cannot be directly tested but the availability of ample information is important to define a vector of explanatory variables that makes the assumption as plausible as possible.

Since our aim is to examine whether firms with different levels of engagement in innovation activities attach a different importance to barriers, we define different kinds of treatments according to the number of innovative activities that firms are carrying out (as reported in the Spanish Innovation Survey). For each treatment definition we estimate, as mentioned above, the probability of being treated, that is the probability that a firm carries out a certain number of innovative activities (according to the definition of treatment taken into account). We then find, for each treated unit, one or several non-treated units that have the same (or a sufficiently close) estimated probability of carrying out the same number of innovative activities.

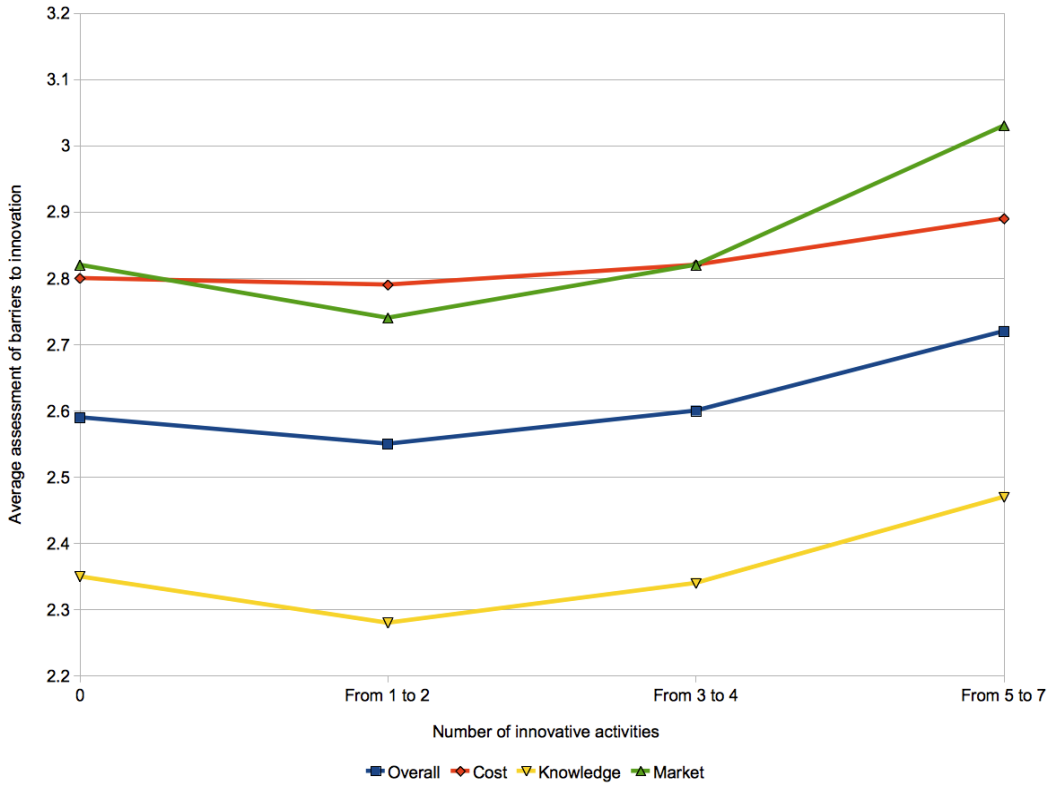
We then compare these groups of firms in terms of the average assessment of barriers to innovation (our outcome variable) as reported by the firm in the survey, thus testing for differences in mean assessment rates of innovation barriers for treated and non-treated units. Not only this provides an estimate of the average treatment effect on the treated, but we are also able to identify a pattern in the assessment of barriers to innovation along the extent of innovative activities carried out. In this way, we extend and generalize the distinction proposed by D'Este et al. (2008), by providing an empirically grounded threshold based on the extent of the engagement of firms in innovation activities.

4 Findings

4.1 Revealed and deterring barriers to innovation: towards an operational distinction

By plotting the average assessment of barriers to innovation against the number of innovative activities (see Figure 1), we note an interesting relationship between the two characteristics, i.e. a clear U-shaped pattern. In particular, it looks like that firms reporting a modest number of innovative activities (1 or 2) tend, on average, to report barriers to innovation as less important compared to other firms (those that do not carry out innovative activities at all and those that report a medium-high number of innovative activities).

Figure 1: Curvilinear relationship between importance of barriers to innovation and number of innovative activities



This behaviour is consistent with our argument in favour of a differentiation between deterring and revealed barriers to innovation. Interestingly, the U-shaped pattern, that is valid for the overall assessment of barriers to innovation, seems to be driven mainly by knowledge and market barriers to innovation rather than cost barriers. In the latter case, the average assessment, although increasing for firms reporting a medium and high number of innovative activities, seems not to be different between firms reporting no innovative activities and those characterised by a modest number of them. A similar pattern can be found in Table 3, where we provide some descriptive statistics for all the firms contained in our sample and for the groups of firms according to the number of innovative activities.

Table 3: Descriptive statistics by groups of firms according to the number of innovative activities

	All observations (N=5330)				Non innovators* (N=1300)				Modest innovators** (N=2810)				Moderate and strong innovators*** (N=1220)			
	mean	sd	min	max	mean	sd	min	Max	mean	sd	min	max	mean	sd	min	max
ObsTot	2.57	0.67	1	4	2.59	0.7	1	4	2.55	0.67	1	4	2.62	0.62	1	4
ObsCost	2.8	0.94	1	4	2.8	0.96	1	4	2.79	0.94	1	4	2.83	0.9	1	4
ObsKnow	2.32	0.8	1	4	2.35	0.86	1	4	2.28	0.79	1	4	2.37	0.74	1	4
ObsMkt	2.79	0.95	1	4	2.82	0.96	1	4	2.74	0.96	1	4	2.85	0.9	1	4
NInn	1.63	1.4	0	7	0	0	0	0	1.47	0.5	1	2	3.71	0.9	3	7
Size	4.19	1.5	0	10.02	4.02	1.55	0	8.65	4.14	1.44	0	10.02	4.48	1.57	0.69	9.93
Startup	0.07	0.25	0	1	0.03	0.17	0	1	0.07	0.25	0	1	0.11	0.32	0	1
HumCap	26.44	27.42	0	100	17.29	23.75	0	100	28.02	27.7	0	100	32.56	28.02	0	100

Note: (*) "non-innovators", firms reporting no innovative activities; (**) "modest innovators", firms reporting 1 or 2 innovative activities; and (***) "moderate and strong innovators", firms reporting 3 to 7 innovative activities.

However, the figures presented in Table 3 and the visual representation of Figure 1, are simple descriptive comparisons. They show that a different behaviour 'might' be present among the firms in our sample according to the level of innovation carried out and that these firms are likely to face different kinds of barriers to innovation.

We now turn to examine whether these differences still hold, once we explicitly consider all of the factors that may influence the probability of carrying out different levels of innovative activities. To do that, we rely on the propensity score matching procedure explained in Section 3.4. The main purpose is to compare the rate of barriers' assessment of firms carrying out a different number of innovative activities with those of an appropriate control group.

We do this by taking into consideration three treated groups: (i) "non-innovators" (firms reporting no innovative activities), (ii) "modest innovators" (firms reporting 1 or 2 innovative activities) and (iii) "moderate innovators" (those reporting 3 or 4 innovative activities). We compare each one of them with several control groups. For instance, for the "non-innovators", we compare how the average assessment of barriers to innovation differs from that of a control group composed by firms reporting more than one innovative activity (column 1 in Table 4); from that composed of modest innovators (column 2 in Table 4), from moderate innovators (column 3 in Table 4), and finally from strong innovators (column 4 in Table 4).[13] We then compare the group of "modest innovators" with a group of controls drawn from moderate (column 5 in Table 4) and strong innovators (column 6 in Table 4). And

[13] Strong innovators are defined as those firms that report a number of innovative activities between 5 and 7.

finally, the last comparison is done between the group of moderate innovators and a control group containing strong innovators (column 7 in Table 4).

Table 4 shows the difference between the average assessment of barriers to innovation of the treated and control groups that constitutes the Average Treatment for the Treated (ATT) estimation procedure. A positive and significant difference is found between non-innovators and modest innovators while a negative and significant difference is present between modest innovators and groups of controls that are moderately and strongly innovative as well as between moderate and strong innovators. Interestingly, no significant difference is found between non-innovators and control groups containing firms carrying out more than 3 innovative activities.

Table 4: Average Treatment on the Treated (ATT) estimation of the average assessment of barriers to innovation

	Non-innovators vs innovators †	Non-innovators vs modest innovators†	Non-innovators vs moderate innovators†	Non-innovators vs strong innovators‡	Modest innovators vs moderate innovators†	Modest innovators vs strong innovators‡	Moderate innovators vs strong innovators‡
Overall							
ATT	0.045*	0.06*	-0.001	-0.084	-0.05*	-0.2**	-0.13**
SE	0.02	0.03	0.04	0.06	0.02	0.05	0.04
N treated	1300	1300	1300	1298	2810	2796	999
N controls	4030	2810	1002	3812	1002	2519	4283
Cost barriers							
ATT	0.013	0.03	-0.02	-0.09	-0.02	-0.17*	-0.12**
SE	0.03	0.04	0.05	0.1	0.03	0.06	0.05
N treated	1300	1300	1300	1298	2810	2796	999
N controls	4030	2810	1002	3812	1002	2519	4283
Knowledge barriers							
ATT	0.06*	0.07**	0.009	-0.02	-0.07*	-0.16**	-0.11*
SE	0.03	0.03	0.04	0.07	0.03	0.05	0.05
N treated	1300	1300	1300	1298	2810	2796	999
N controls	4030	2810	1002	3812	1002	2519	4283
Market barriers							
ATT	0.07*	0.1**	0.007	-0.16	-0.08**	-0.3**	-0.2**
SE	0.03	0.03	0.05	0.1	0.03	0.06	0.05
N treated	1300	1300	1300	1298	2810	2796	999
N controls	4030	2810	1002	3812	1002	2519	4283

† *ATT estimation with the kernel propensity score matching with bootstrapped standard errors (100 replications)*

‡ *ATT estimation with the stratification method*

* p<0.05, ** p<0.01

The results from the propensity score matching confirm the outcome obtained via descriptive and visual inspections. In particular, we find that a non-innovator is likely to rate barriers to innovation as more important compared to modest innovators, while a modest innovator tends to rate barriers as less important compared to firms that are more strongly engaged in innovation activities, i.e. those carrying out a higher number of innovative activities. This confirms the U-shape pattern in the relationship between the number of innovative activities a firm carries out and its assessment of barriers. We moreover find that this overall pattern is actually driven by knowledge and market barriers while we do not find such a pattern for cost barriers.

In short, there are a number of implications emerging from the results shown in Table 4. Building upon the evidence of a U-shaped relationship between engagement in innovative activities and assessment of barriers as important, we can argue that a particular group of firms (i.e. the "non-innovators") are particularly likely to face deterring barriers: that is, barriers that prevent them from starting innovation activity. The matching procedure helps us to conclude that, when compared with groups of firms of similar characteristics that engage only modestly in innovation activities, "non innovators" are experiencing significantly stronger barriers to innovation.

Moreover, there are other groups of firms (i.e. moderate and strong innovators) for which obstacles increase alongside their engagement in innovative activities. Thus, these firms are likely to be facing revealed barriers, in the sense that their awareness of factors hindering innovation do not prevent them from pursuing innovation-related activities. In between the two, there is a group of firms composed by modest innovators that are probably facing a mix of the two kinds of obstacles; in other words, these firms are located in a blurred grey zone that makes it difficult to unambiguously classify as either experiencing only deterring barriers or revealed barriers to innovation.

We now turn our attention more directly to these two groups of firms: those facing deterring barriers and those facing revealed barriers. In particular, in Section 4.2 we examine the impact of the expected attenuating factors on the two types of obstacles (knowledge and market barriers) comparing those firms facing deterring barriers versus those facing revealed barriers.

4.2 Factors attenuating the assessment of barriers to innovation: a comparison of revealed and deterring barriers

In this section we concentrate on the empirical test of the hypothesis proposed in Section 2 concerning individual and environmental factors that are likely to attenuate deterring barriers as opposed to revealed ones. In particular, we systematically compare the results for the two samples of firms: those confronting deterring barriers and those facing revealed barriers as they have been defined in the previous section. We moreover control for a number of firm and industry features: e.g. the internationalisation of its customer base and industrial sector dummies.

The empirical analysis is based on a logistic model that takes into consideration two dependent variables, differentiating between knowledge and market obstacles[14]. The dependent variables are dichotomous, indicating whether the firm assesses as highly important at least one barrier item.[15] The estimation is conducted on two related sub-samples.

On the one hand, firms facing deterring barriers to innovation: that is, the group of firms that have not been engaged in innovation activities. Since non-innovators report their assessment on how important knowledge and market obstacles are, we define two dependent variables: one related to knowledge barriers (KNOW_DET) and another one related to market barriers (MKT_DET).

On the other hand, we consider firms facing revealed barriers: that is, the group of firms that engage in 3 or more innovative activities (the moderate and strong innovators). As in the previous case, these firms report their assessments on both knowledge and market barriers, so we consider two dependent variables: one related

[14] On the grounds of the findings obtained in Section 4.1, cost barriers are not taken into account in the estimation of factors influencing the assessment of innovation obstacles. Indeed, in the latter case no clear U-shaped relationship is found to hold and, for this reason, we are not able to differentiate between firms facing deterring barriers as opposed to those facing revealed ones.

[15] We also estimated an ordered logistic regression by considering as dependent variable the number of barrier items assessed as highly important by the firm. Results do not differ significantly from the ones provided here for the logistic model and are reported in the appendix.

to knowledge obstacles (KNOW_REV) and another one related to market obstacles (MKT_REV). The results are reported in Table 5.

Results from Table 5 show a negative and significant coefficient for firm size. In particular, other things being equal, being a larger firm decreases the probability of assessing barriers to innovation as highly important irrespective of facing revealed or deterring obstacles. It is worth stressing that this result is similar for knowledge and market barriers. However, contrary to the hypothesis proposed in Section 2, being a new firm does not seem to influence the probability of assessing barriers as important, with no notable difference between the group of firms facing deterring barriers and those confronting revealed ones.

Interestingly, human capital (i.e. the proportion of employees with a higher education degree) is found to be significant and negatively related to the assessment of the importance of barriers to innovation. In particular, this result is found to hold for those firms confronting deterring barriers to innovation (either knowledge or market related ones), but it is not found for firms confronting revealed barriers. This latter result is quite important because it clearly shows that firms with a higher proportion of highly skilled employees are better positioned to overcome deterring obstacles to innovation in particular.

Sectoral affiliation also has some bearing on the firms' assessment of barriers to innovation, as shown by the fact that some of them turn out to be significant. More specifically, firms in low or medium-tech manufacturing industries exhibit higher knowledge revealed barriers. On the contrary, firms in high-tech service industries exhibit lower levels of revealed market barriers.

Table 5: Results of the logistic model

	Dependent variable: whether the firm assesses at least 1 barrier as highly important			
	KNOW_DET	KNOW_REV	MKT_DET	MKT_REV
Size	-0.18399***	-0.32894***	-0.25744***	-0.16117***
	(0.050)	(0.060)	(0.045)	(0.048)
StartUp	-0.21400	-0.62926	0.45278	0.48756
	(0.453)	(0.397)	(0.389)	(0.331)
HumCap	-0.00998**	0.00414	-0.00568*	0.00177
	(0.003)	(0.004)	(0.003)	(0.003)
PubSupNat	0.19086	0.34571*	0.32212	-0.01581
	(0.293)	(0.175)	(0.270)	(0.153)
PubSupEur	0.74755	0.44347	-0.74038	0.21069
	(0.635)	(0.244)	(0.704)	(0.226)
PubSupLoc	0.53279*	0.15299	-0.04513	-0.12153
	(0.214)	(0.167)	(0.204)	(0.146)
IntMkt	-0.18678	-0.05964	0.05924	0.29220
	(0.141)	(0.206)	(0.128)	(0.186)
InnInt	-0.00090	-0.00017	0.00007	0.00024
	(0.003)	(0.000)	(0.001)	(0.000)
InnExp	-0.15277	-0.01583	0.14828	-0.52912
	(0.187)	(0.542)	(0.165)	(0.437)
IndMLT	-0.46989	0.67690*	-0.53496	-0.05865
	(0.381)	(0.277)	(0.344)	(0.224)
IndMMT	-0.11311	0.56610*	-0.27116	-0.05402
	(0.353)	(0.279)	(0.322)	(0.223)
IndSLT	-0.04987	0.24119	0.16120	0.26940
	(0.425)	(0.316)	(0.384)	(0.264)
IndSHT	-0.08046	0.03288	-0.53547	-0.63904*
	(0.373)	(0.318)	(0.340)	(0.265)
Cons	-0.01839	-0.73345	0.86252*	0.09186
	(0.389)	(0.583)	(0.358)	(0.478)
Chi2	39.84621	76.34295	72.59815	57.02215
N	1300	1220	1300	1220
Log-likelihood	-704	-603	-817	-745

* p<0.05, ** p<0.01, *** p<0.001.

Building upon the results in Table 5, we provide a visual representation of the negative impact of "human capital" on the estimated probabilities of assessing deterring barriers as highly important (with all other variables measured at their means), differentiating between knowledge (Figure 2) and market barriers (Figure 3). The figures show that having a larger share of skilled employees attenuates the deterring effect of knowledge and market obstacles to innovation.

Figure 2: Impact of human capital on the assessment of knowledge obstacles to innovation

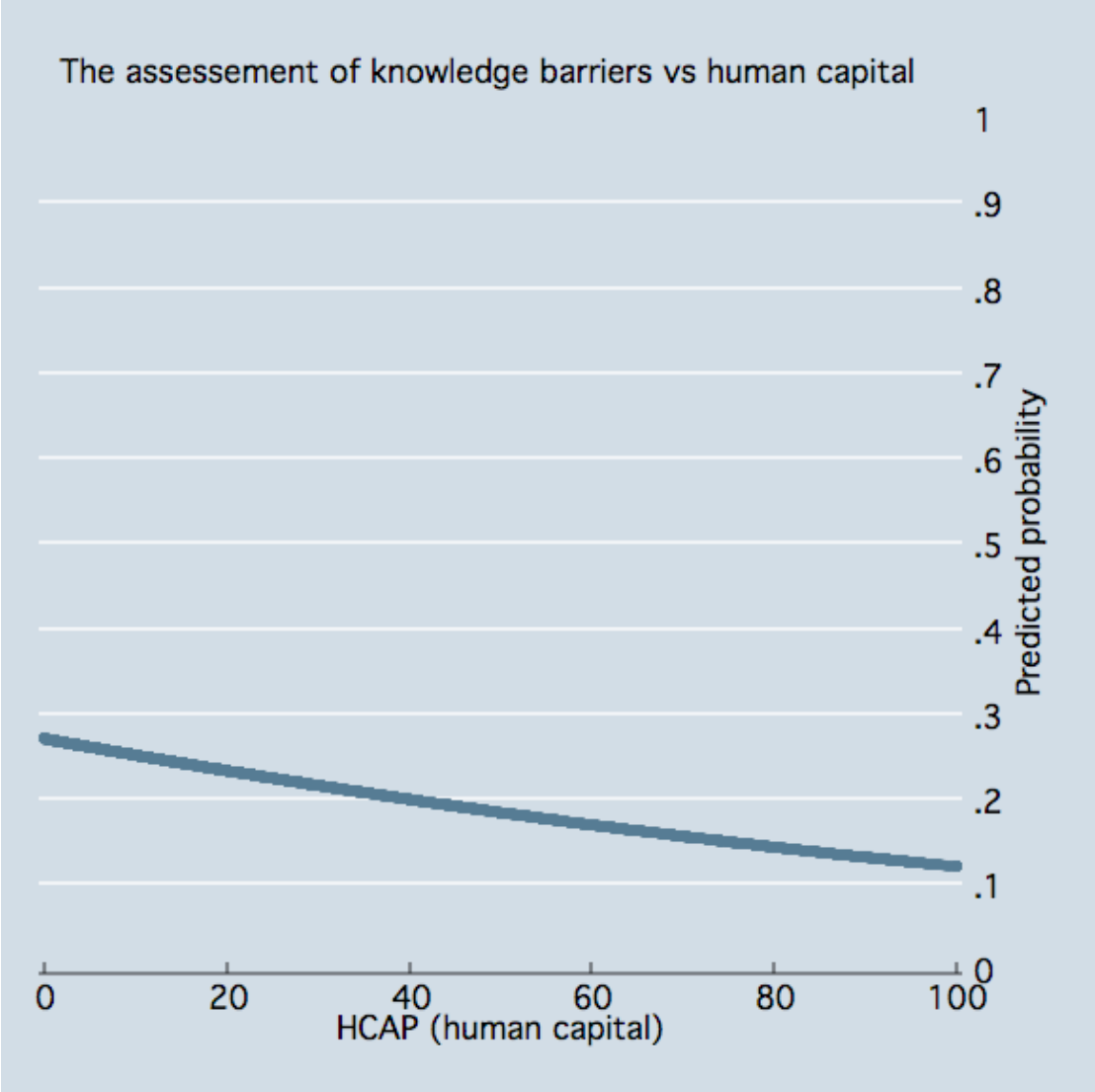
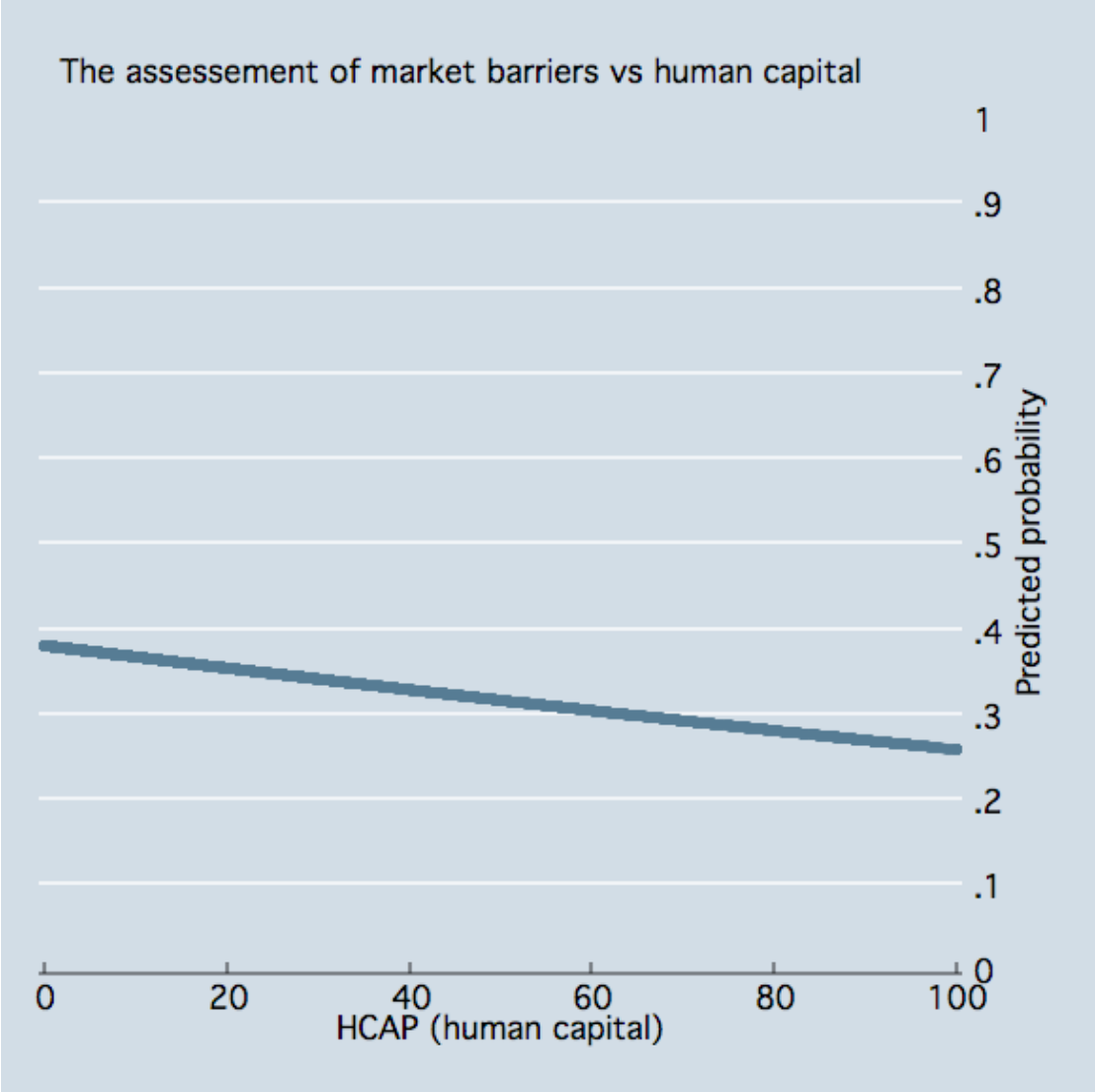


Figure 3: The impact of human capital on the assessment of market obstacles to innovation



5 Discussion and conclusions

Despite the fact that innovation is often seen to be the key to a firm's economic success, not all firms willing to innovate engage in innovation activities. As this paper shows, about 30% of our sample of "potential innovators" do not engage in *any* innovative activity, and another 50% engage only modestly (i.e. in two innovation-related activities at most). This raises the issue about why firms are deterred from innovation and what factors may attenuate the obstacles faced by firms to engage in innovation activities. These are the main questions addressed in this paper.

The paper contribution is threefold. First, the paper shows that there is a U-shaped relationship between the level of engagement in innovative activities and the assessment of barriers. This is important since it confirms that, indeed, non-innovators are extremely sensitive to barriers to innovation: they actually assess barriers as significantly more important compared to firms involved modestly in innovation, and their assessments are similar to firms involved strongly in innovation related activities.

This curvilinear relationship highlights, first, that there are actually different groups of firms that perceive high "levels" of barriers to innovation; and second, that the barriers experienced by each group are of a different kind. While firms in one group (i.e. those firms not engaged in innovative activities) are likely to face obstacles that deter them from engaging in innovation activities, firms in the other group (i.e. those strongly involved in innovative activities) are likely to face obstacles that are revealed alongside their engagement in innovation-related activities. Our results here support previous findings for the UK (see D'Este et al., 2008) and provide a line of response to the counter intuitive finding in much of the literature on obstacles to innovation based on innovation surveys that shows a positive and significant impact of constraints on the likelihood to have innovative activities (Baldwin and Lin, 2002; Mohnen and Roller, 2005; Savignac, 2008).

Second, the paper shows that market and knowledge barriers are playing a much more important role than cost-barriers as deterring mechanisms to innovation activities. Financial constrains have often been the focus of most of the empirical literature on obstacles to innovation. Moreover, as confirmed in this study, financial-related barriers are often the most prevalent among survey respondents. However, our findings show that cost-related barriers are particularly strong among firms heavily engaged in innovation activities. In other words, firms seem to be more strongly deterred from innovation by factors such as market conditions (i.e. 'market dominated by established firms' or 'uncertain demand for innovative products') and knowledge (i.e. 'lack of qualified personnel' or 'lack of information on technology'), than by financial-related obstacles.

Without doubt, it would be important to replicate this study in different settings in order to check for the robustness of the findings. Nevertheless, these findings provide preliminary evidence that points towards policy measures to promote innovation that expand well-beyond the availability of finance and the response to imperfect financial markets. Instead, they point towards policies addressing systemic failures on innovation associated with the weaknesses of the research infrastructure, the lack of technological capabilities among firms, and the entry barriers emerging from highly concentrated markets (among others).

Third, this research has also addressed the extent to which certain firm characteristics alleviate deterring and revealed obstacles to innovation. In this respect, our findings indicate the following. Small firms seem to be clearly disadvantaged to face both deterring and revealed barriers on innovation. As expected, large firms seem to benefit from economies of scale and scope that attenuate the importance of obstacles to innovation. In this sense, policy initiatives oriented to support risky projects by small firms should be welcomed.

However, we have not found support for the hypothesis that start-up firms are particularly sensitive to deterring barriers on innovation. Rather, being a new-established firm does not seem to imply either an advantage or a disadvantage to face deterring or revealed barriers. Additionally, our results do not support either that deterring barriers are particularly prevalent among firms in high-tech sectors. One of the future avenues of this research is to investigate whether there is any interaction effect between these to features (i.e. start-ups and high-tech industries), with regards to the assessment of barriers.

Finally, our findings point out that firms with a highly educated workforce are better equipped to face deterring barriers on innovation, with regards to both knowledge and market barriers. This result points out the importance of a science and technology infrastructure (and of universities in particular) as suppliers of a talented workforce in order to avoid a shortage of skills available on the market; but also highlights the importance of raising awareness among firms about the need to introduce the organisational changes required to continuously upgrading their skill-base.

This study has a number of limitations. On the one hand, our sample of non-innovators is likely to be underrepresented (this type of surveys tend to have an overrepresentation of firms that carry out innovative activities), and therefore we need to be cautious about making inferences to the whole population of firms, and particularly to "potential innovators" that do not carry out innovation activities. On the other hand, we have not introduced explicitly (besides industry controls) the role of environmental factors in shaping the assessment of firms about barriers. We plan to address this latter issue more explicitly in future work.

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Appendix

Ordered logistic regression

Dependent variable: number of barrier items assessed as highly important

	KNOW_DET	KNOW_REV	MKT_DET	MKT_REV
Size	-0.34987***	-0.29422***	-0.24023***	-0.15127**
	(0.042)	(0.042)	(0.044)	(0.047)
StartUp	0.12833	0.69683*	0.39678	0.49017
	(0.336)	(0.291)	(0.359)	(0.308)
PubSupLoc	0.13567	-0.09264	-0.07723	-0.08109
	(0.181)	(0.129)	(0.198)	(0.142)
PubSupNat	-0.23961	0.16471	0.45256	-0.03844
	(0.248)	(0.134)	(0.261)	(0.150)
PubSupEur	0.43480	0.35481	-0.73055	0.23790
	(0.542)	(0.196)	(0.696)	(0.220)
HumCap	-0.00600*	-0.00346	-0.00645*	0.00065
	(0.003)	(0.003)	(0.003)	(0.003)
IntMkt	0.15968	0.12740	0.03959	0.25281
	(0.114)	(0.158)	(0.124)	(0.182)
InnInt	-0.00330	0.00046	-0.00001	0.00012
	(0.004)	(0.000)	(0.001)	(0.000)
InnExp	-0.02134	-0.36358	0.12943	-0.59984
	(0.148)	(0.384)	(0.159)	(0.426)
IndMLT	0.08852	-0.46641*	-0.77040*	-0.07059
	(0.304)	(0.199)	(0.334)	(0.218)
IndMMT	-0.04534	-0.41969*	-0.50536	-0.06423
	(0.287)	(0.196)	(0.312)	(0.217)
IndSLT	0.45259	-0.17273	0.00162	0.26755
	(0.342)	(0.238)	(0.370)	(0.255)
IndSHT	-0.20640	-0.41409	-0.74699*	-0.59026*
	(0.303)	(0.224)	(0.331)	(0.260)
cut1				
_cons	-1.47301***	-1.48949***	-1.03669**	-0.10963
	(0.324)	(0.424)	(0.347)	(0.468)
cut2				
_cons	-0.53561	-0.57649	0.41963	1.44980**
	(0.321)	(0.422)	(0.348)	(0.472)
cut3				
_cons	0.29924	0.36879		
	(0.323)	(0.424)		
Chi-square	126.55685	109.78045	75.24658	52.60688
N	1300	1220	1300	1220
Log-likelihood	-1550	-1430	-1120	-991

* p<0.05, ** p<0.01, *** p<0.001